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June 1996

ACOUSTIC CALIBRATION TESTS OF THE 219 PROJECTOR

Garry Heard — Ross Chapman
Mark Rowsome — Terry Miller

Defence Research Establishment Atlantic

Centre de Recherches pour la Défense Atlantique

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Abstract

This report is intended to serve as an introduction to the 219 Moving Coil Projector and presents the measured response curves for the frequency range 50 - 200 Hz. Two different coil assemblies were tested and the measured response curves for both units are presented. Calibration of the projector's pressure sensor is also included to allow for accurate tow-depth determination. The projector's harmonic distortion was measured and its effect on a broadband signal presented. Finally, typical towing characteristics (tow-angle, tow-depth, and cable scope) are summarized for a nominal tow-speed of 3.5 knots.

Essais d' étalonnage acoustique du projecteur 219

Résumé

Ce rapport vise à servir d' introduction au projecteur à bobine mobile 219, et il présente les courbes de la réponse mesurée pour la gamme de fréquences 50 - 200 Hz. Deux ensembles à bobine différents ont été soumis à des essais, et les courbes de réponse mesurées pour les deux unités sont présentées. L' étalonnage du capteur de pression du projecteur est également inclus afin de permettre la détermination précise de la profondeur de remorquage. La distorsion harmonique du projecteur a été mesurée, et son effet sur un signal à large bande est présenté. Enfin, les caractéristiques de remorquage typiques (angle de remorquage, profondeur de remorquage et portée du câble) sont résumées pour une vitesse de remorquage nominale de 3,5 noeuds.

DREA TM/96/219

Acoustic Calibration Tests of the 219 Projector

by

Garry J. Heard, N.R. Chapman, M. Rowsome, T. Miller

EXECUTIVE SUMMARY

INTRODUCTION

The 219 Moving Coil Projector (219 MCP), originally developed by Maritime Resource Industries (MRI), has been extensively employed for underwater acoustics research. Recently, a series of calibration tests were undertaken in the quiet waters of Jervis Inlet to measure the acoustic output of the 219 MCP in its most commonly used frequency band. This report presents the results of these calibration and other measurements undertaken to directly support the international cooperative field trial SWELLEX-4 with participants from MPL/SCRIPPS and NCCOSC RDT&E in the USA, and EDRD in Canada.

PRINCIPAL RESULTS

This report presents the following principal results:

- description of projector system;
- projector calibration measurements for two coil assemblies in frequency range 50-200 Hz;
- depth sensor calibration;
- harmonic distortion measurements; and
- typical towing characteristics.

SIGNIFICANCE OF RESULTS

The data provided in this report will allow researchers to calibrate the source level of radiated acoustic signals from this projector and will provide useful information on the deployment and operation of the 219 MCP. The data are particularly useful for the analysis of SWELLEX-4 data.

FUTURE PLANS

No further calibration measurements are planned for the 219 MCP. These acoustic projectors remain at EDRD and are available for use in other experiments.

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1. Introduction

In preparation for the SWELLEX 4 sea test, *CFAV Endeavour* was deployed in March 1995 to Jervis Inlet where work-up trials with the 219 Moving Coil Projector (219 MCP) were undertaken. Tests conducted in Jervis Inlet included calibrating the depth sensor, measuring the projector response, checking projector linearity, estimating signal quality and purity, and measuring typical tow characteristics.

The 219 MCP system consists of a coil-driven piston situated behind a watertight neoprene covering, a passive pressure compensation bladder, a protective steel tube, a transformer, and an acoustic and depth monitor sub-system. All of these components are mounted in a small sled (see Fig. 1), which provides the tow cable attachment and minimal streamlining. The passive pressure compensation is achieved by hydrostatically compressing air, initially just above atmospheric pressure, contained in a bladder located within the protective steel tube. As the transducer is lowered into the water, the bladder collapses to balance the external pressure. The 219 MCP has replaceable coil assemblies made by two manufacturers. The older coils are referred to as the MRI 219 heads, while the newer coil is referred to as the Argotec 219 head.

The sled assembly is towed by a 3/8" braided wire tow cable with seven internal conductors. The tow-cable is passed through a block mounted in a small A-frame at the rear of the ship. The A-frame angle is hydraulically adjustable to facilitate deployment and recovery of the projector. Figure 2 shows the winch with automatic level-wind that is used to raise and lower the projector.

The acoustic and depth monitoring sub-system was developed under contract to JASCO Research Ltd.[1] This sub-system collects a sample of acoustic data and a depth measurement, and combines them with a date-time stamp in preparation for transmission to a PC computer in the ship's laboratory via an RS-422 communications line. The data monitoring is not continuous, the duty cycle is about 50%. Typically, 16 seconds worth of acoustic data are collected and then transmitted to the ship at 38.4 kbaud twice a minute. One of the most important goals of the trial was to test the operation of this sub-system and to use it to aid in the estimation of the projector response.

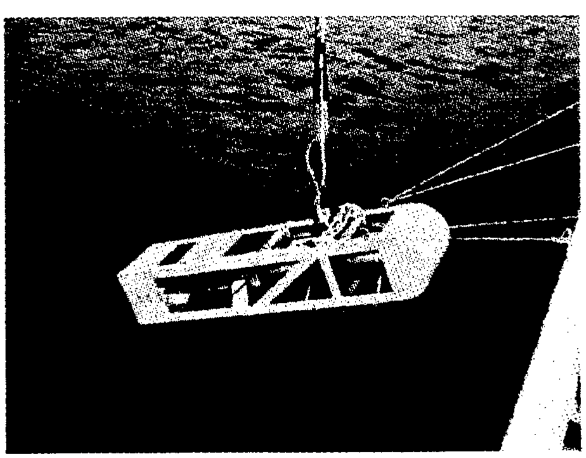

Figure 1. The MCP sled.

Figure 2. The projector winch.

2. Depth Sensor Calibration

The first task carried out was to calibrate the depth sensor. The depth estimate is derived from a pressure gauge connected to the A/D (analogue-to-digital convertor) system. The A/D returns an integer value between 0 and 1023 for input voltages 0-2.5 V. It was necessary to convert the A/D units to meaningful depth values. This was done by mooring the Endeavour to a Navy Buoy in Jervis Inlet and lowering the 219 MCP off the stern of the ship while measuring the length of cable deployed. Figure 3 shows the variation of the A/D output as a function of the projector depth. By fitting a straight line to the set of points (depth-vs-A/D counts) it was possible to calibrate the A/D output to read directly in meters of depth. The details are summarized in the following equation

$$D = 0.0922 \bullet I - 21.18, \qquad (1)$$

where D is the depth in metres, and I is the A/D reading. Repeated measurements indicate that the accuracy of the depth measurement is approximately ±30 cm.

3. Projector Response

The second task carried out during the Jervis Inlet work-up trials was to estimate the projector response. The response was estimated by Fourier analyzing recorded data segments from the monitor hydrophone and correcting for the known response of the hydrophone and associated electronics. This task was carried out for the Argotec 219 head and for one of the MRI 219 heads. Most of the tests were conducted with the Argotec head as it is the primary

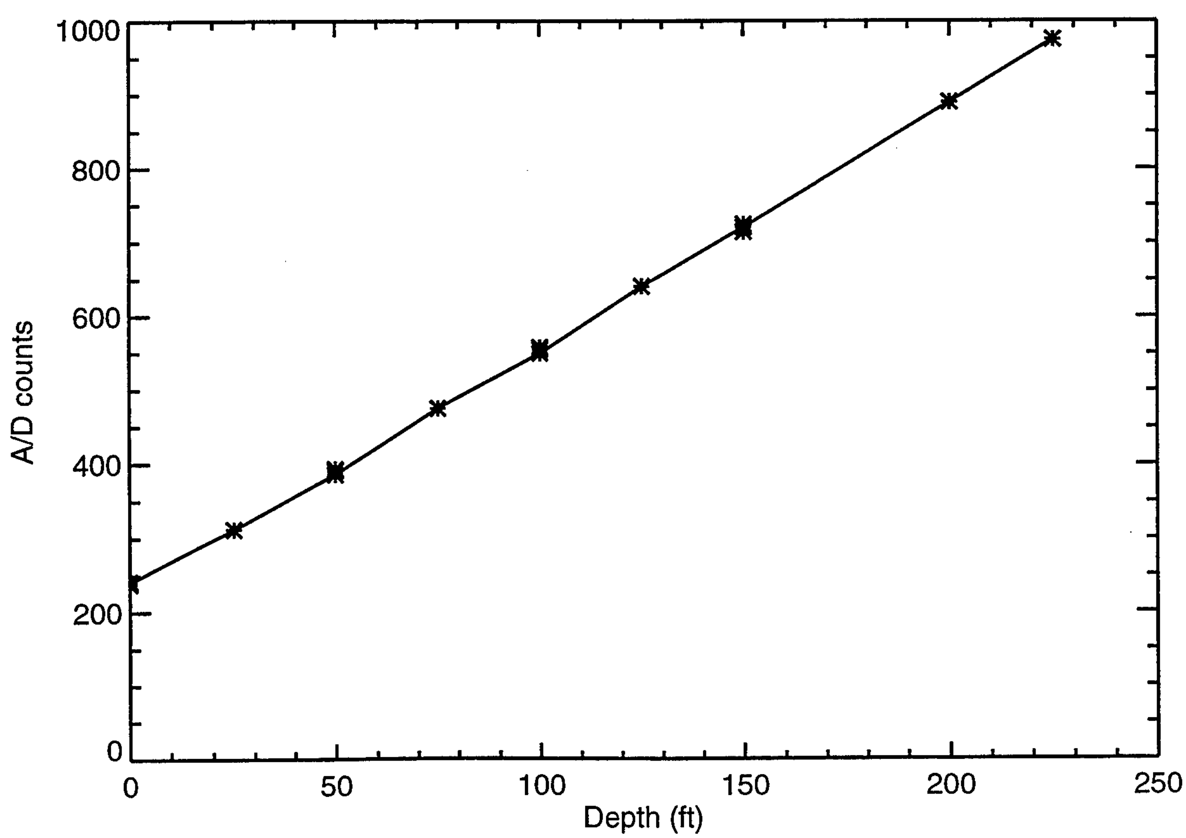

Figure 3. Projector depth sensor calibration.

magnet-coil assembly and is capable of higher acoustic source levels than the MRI head.

In order to estimate the peak amplitude of the received acoustic data, power spectra were computed from chunks of data 16384 samples in length. The data were sampled at 1000 Hz. A smoothing window was not applied, but the resulting losses due to spectral leakage appear to be less than the experimental uncertainties, which are estimated to be approximately 2-3 dB. The resulting power spectra were scaled to provide a direct measurement of the amplitude of the sine wave signal and the spectral values were converted to decibels relative to 1 volt peak.

The power spectral values must be converted to acoustic source level (*SL*) by taking account of the gains of the various system components. The monitor hydrophone has a rated sensitivity of -193 dB//1V/μPa and is attached to an amplifier that has a flat response in the frequency band of interest with a constant gain of 6 dB. The output of the amplifier goes directly to the A/D that has a gain of 52.2 dB (1024/2.5 V). Finally, the monitor hydrophone is located 1.3 m from the source, and so, a 2.3 dB correction factor is used to relate the values measured at the hydrophone location to the standard reference distance of 1 m. These factors are summarized by the following equation

$$SL = PSD + 193 - 6 - 52.2 + 2.3 = PSD + 137.1 \qquad (2)$$

where SL is the source level relative to 1 μPa^2 peak, PSD is the power spectral value, and each of the numerical terms represents one of the gains listed above.

Data segments from the monitor hydrophone were collected at various frequencies under two different conditions. First, the spectral values were estimated for data collected with the projector driven at a constant current at each frequency, and second, the spectral values were estimated for data collected with the projector excited by a constant driving voltage. Figure 4 shows the resulting projector response curve for a nominal driving current of 0.5 A rms with the Argotec head. The different symbols represent repeated or independent measurements made at various times during the work-up trial. There is clear evidence of a null in radiated output power near 70 Hz indicating a loss of radiation efficiency. Early in the trial, 60 Hz contamination was present in the monitor hydrophone data. This problem was cured by grounding the monitor system with the result that the measured radiated signal levels at 100 Hz improved significantly. The diamond and asterisk symbols represent measurements made before correcting the ground problem, while the square and triangle symbols represent measurements made after correcting the ground problem. From Fig. 4, it can be seen that the projector will produce an almost uniform output level (±1 dB) of 172 dB//1μPa at 1 m for a drive current of 0.5 A rms for frequencies 90-190 Hz.

Figure 5 shows the projector response curve for the Argotec head driven by a constant voltage of 140 V rms. These measurements were made before correcting the ground problem, and thus show a loss of output at 100 Hz that is not believed to exist. The response curve is very similar to the constant current response curve shown in Fig. 4. This implies that the projector impedance is nearly constant over the frequency band studied.

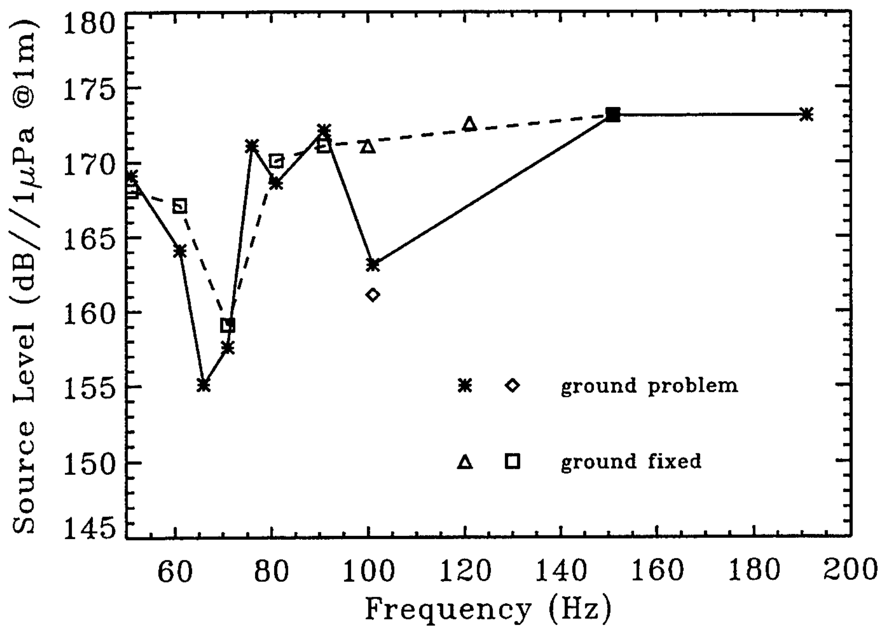

Figure 4. The projector response for a constant driving current of 0.5 A rms with the Argotec head.

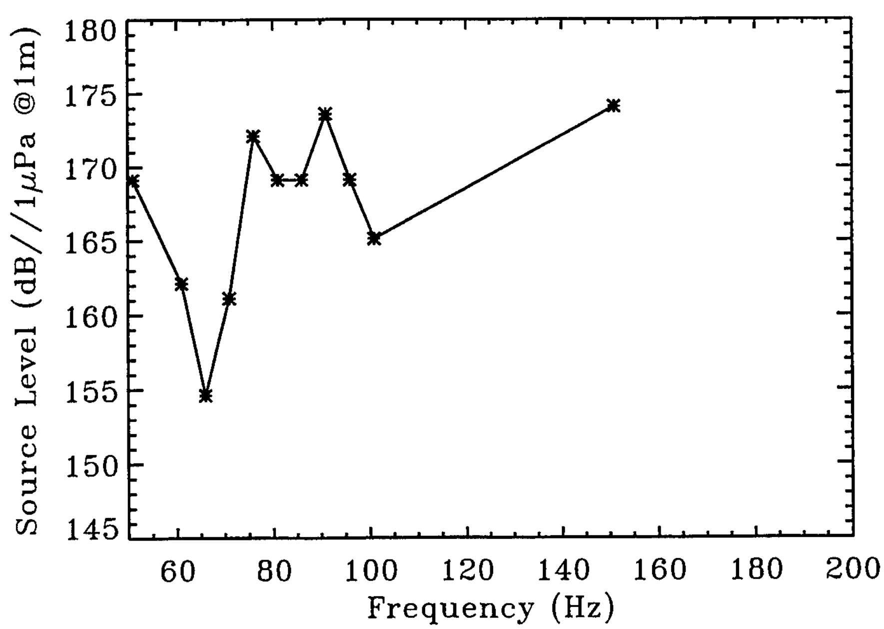

Figure 5. The projector response for a constant driving voltage of 140 V rms with the Argotec head.

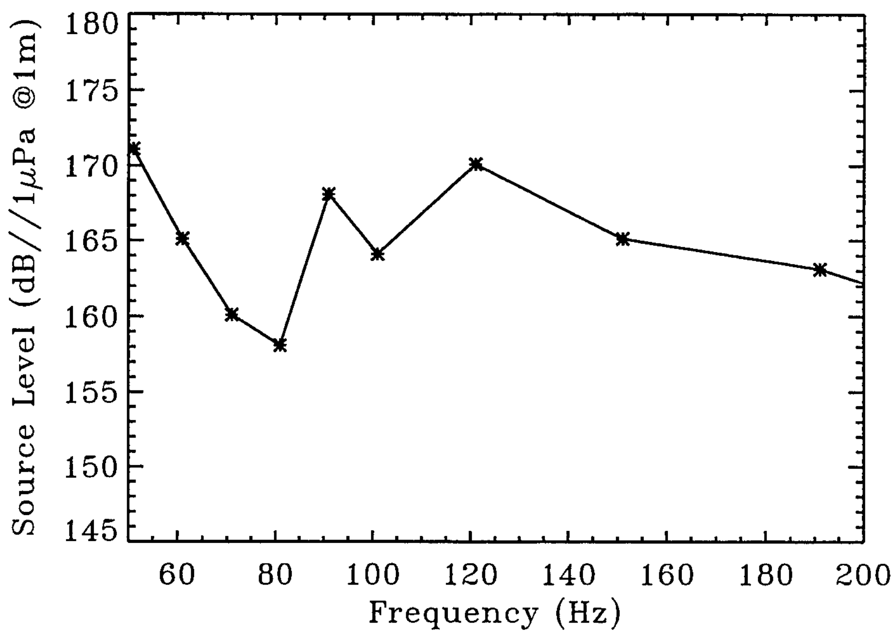

Figure 6. The projector response for a constant driving current of 0.5 A rms with the MRI head.

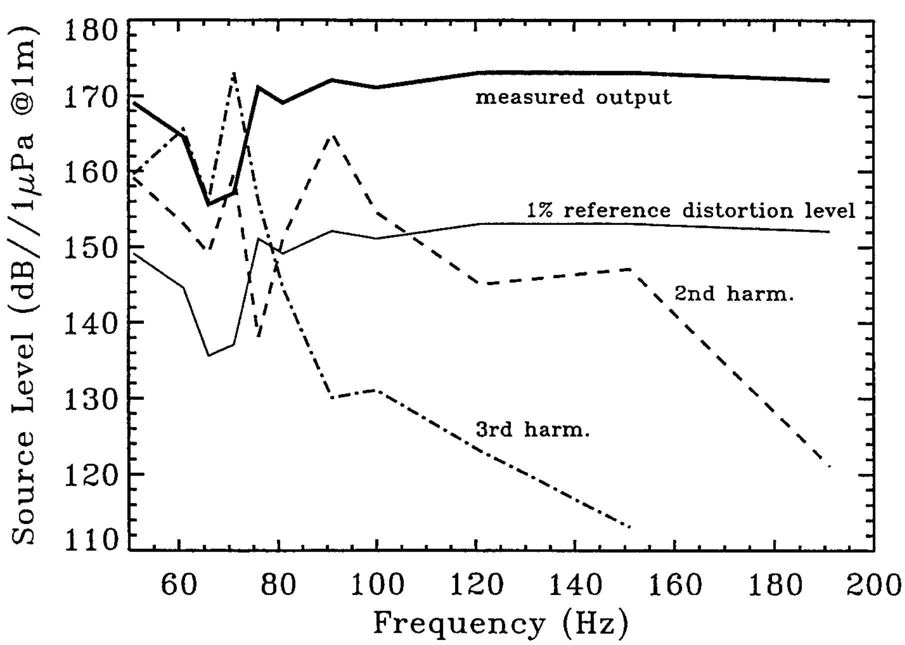

Figure 7. Second and third harmonic levels as a function of frequency. The heavy solid line indicates the measured fundamental level, while the light solid line 20 dB below the drive signal represents a 1% total harmonic distortion reference level.

Figure 6 shows the projector response for the MRI head. This head is not generally capable of the *SL* available from the Argotec head, except at frequencies below 70 Hz where it is possible to exceed the Argotec levels. Above 70 Hz, the MRI output levels are generally 5-10 dB below the Argotec levels.

4. Harmonic Distortion

A measure of the linearity of the projector is available by examining harmonic distortion as a function of frequency. Figure 7 shows the measured source level of the Argotec 219 head as a function of frequency (heavy solid line). A shifted version (-20 dB) of the measured *SL*, shown as a light solid line, represents a reference level of 1% total harmonic distortion. Also shown in the figure, are the measured *SL* of the second and third harmonics (dashed-line and dash-dot line, respectively). The harmonic levels readily exceed the 1% reference level for frequencies below 100 Hz, but for higher frequencies, the projector has reasonable fidelity. The worst distortions occur at frequencies near 70 Hz, where we have previously noted a drop in the radiated output. In fact, near 70 Hz, the distortion levels actually exceed the measured fundamental level. While high fidelity reproduction is not generally required in underwater acoustics research, caution should be applied when using this projector for broadband or coded signal work at frequencies below 120 Hz.

5. Broadband Response

To investigate the projector response with a broadband signal, a segment of data was collected with the monitor system while transmitting the JOER.WAV signal. This signal is composed of 50 simultaneously transmitted tones each separated by 3 Hz, arranged in 5 groups with relative *SL* of 0, -10, -14, -18, and -22 dB. Table 1 lists the 50 frequencies used and the relative levels of each frequency group. These data were Fourier analyzed and the source level spectrum is shown in Figure 8. Note that the strongest tones (52 Hz, 67 Hz, 82 Hz, ..., 187 Hz) are easily found in the spectrum plot. Many of the weaker tones are also detectable. The levels of the tones reflect the characteristics of the calibration response. In addition to the relative line levels, note the presence of the increase in noise at low frequencies. This noise level increase is primarily due to flow noise past the monitor hydrophone. These measurements were made while the projector was under tow at a speed of 4 knots. Note also the broad spectral peak near 50 Hz. This peak is probably due to flow excited vibrations in the monitor and projector systems. Figure 8 shows the projector output at relatively low levels; when the projector is driven harder there is evidence of increased harmonic and intermodulation distortions.

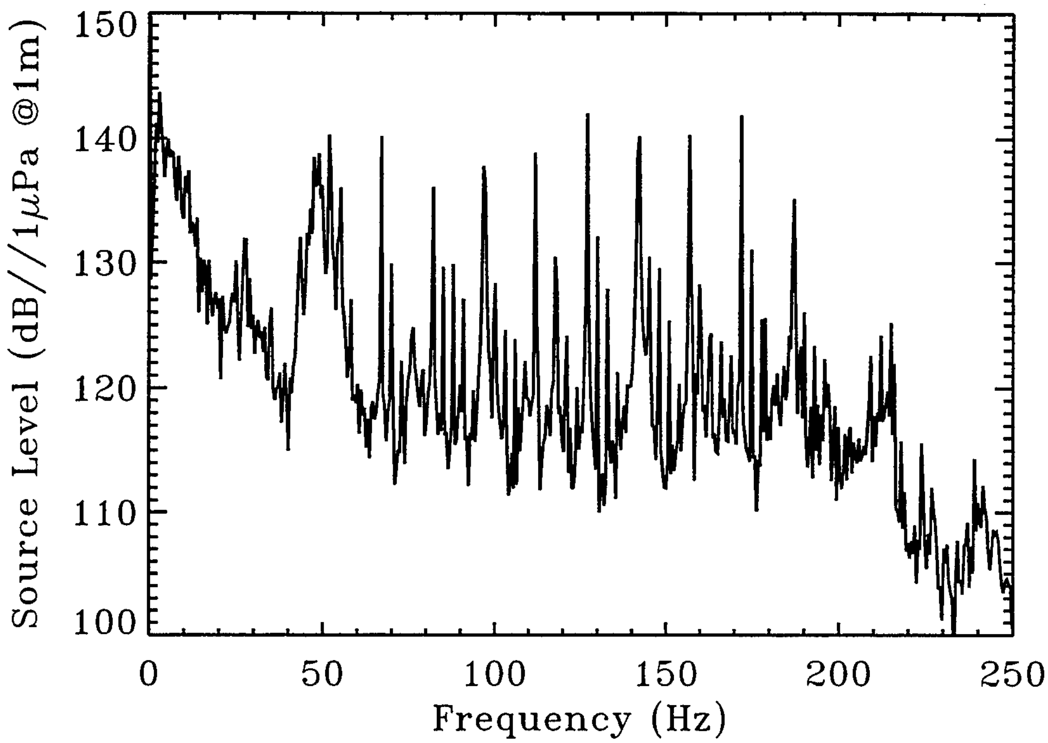

Figure 8. Response of the Argotec 219 projector to the broadband signal JOER.WAV.

Table 1. Frequencies and relative levels of the tonals in the JOER.WAV signal.

0 dB	-10 dB	-14 dB	-18 dB	-22 dB
52 Hz	55 Hz	58 Hz	61 Hz	64 Hz
67	70	73	76	79
82	85	88	91	94
97	100	103	106	109
112	115	118	121	124
127	130	133	136	139
142	145	148	151	154
157	160	163	166	169
172	175	178	181	184
187	190	193	196	199

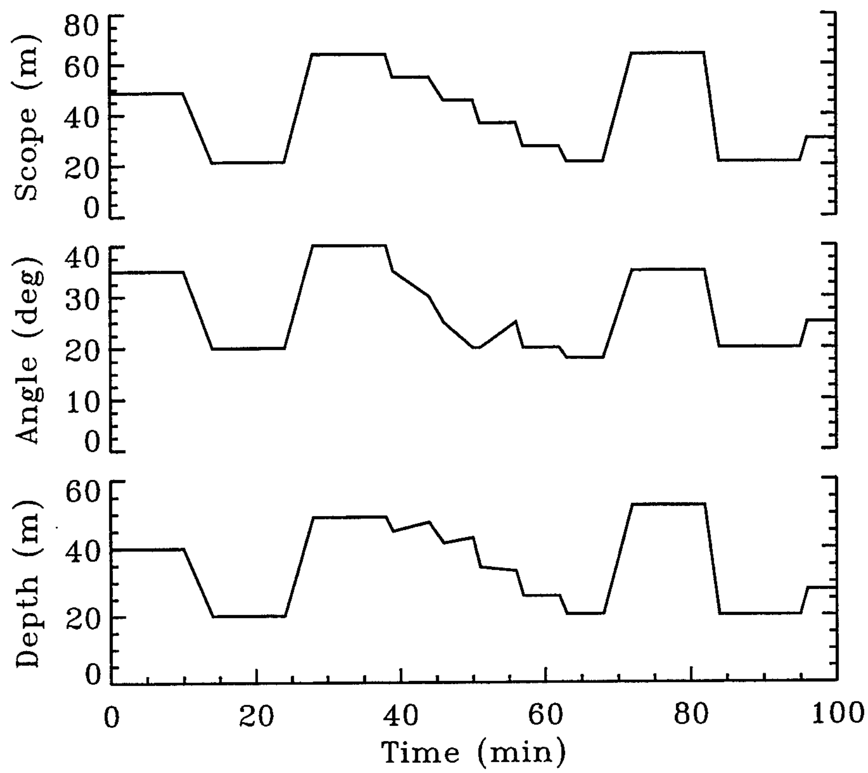

Figure 9. Observed projector towing characteristics at a nominal speed of 3.5 knots.

6. Towing Characteristics

Typical towing characteristics of this projector system are exhibited in Figure 9. This figure shows the cable scope, depression angle and resultant projector depth for a nominal tow-speed of 3.5 knots. These data were collected during the SWELLEX operations, by measuring cable scope and depression angle for a fixed tow-speed of 3.5 knots. The depth was calculated by assuming that the tow-cable was straight, multiplying the cable scope by the cosine of the depression angle, and subtracting the height of the A-frame pulley above the water surface. The depths shown are the result of the simple geometric calculations described above, but are known to be accurate to within about ±2 m through confirmation with the depth sensor in the projector monitoring system. Unfortunately, the monitor system failed during the experiment, so we were unable to measure depth directly during this tow. Depression angles vary in a complicated manner dependent on the cable scope and tow-speed, but they are generally between 20-40° from the horizontal.

7. Conclusions

The 219 projector system is a versatile acoustic transducer capable of relatively high acoustic source levels. The Argotec 219 is capable of higher and more uniform acoustic levels above 80 Hz than the similar MRI 219. Below 80 Hz, both projectors exhibit resonance effects and large variations in acoustic output occur with changing frequency. The MRI 219 is capable of higher output levels at lower frequencies than the Argotec 219.

The fidelity of the projector system is marginal, but more than adequate for most underwater acoustics research applications. Some care must be taken when using broadband signals and best operations generally occur for frequencies above 120 Hz.

The projector is stable during tows and tow depth is easily determined from simple geometric measurements.

The projector monitoring system was a valuable asset without which it would not have been possible to obtain the projector response curves shown in this report.

References

[1] The JSL11A84 Serial Data Aquisition and Control Module, JASCO Research Ltd., #102 - 7143 West Saanich Road, Brentwood Bay, BC, Canada, V8M 1P7.

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